Los Alamos
NATIONAL LABORATORY
EST.1943

LA-UR-18-21022
Approved for public release; distribution is unlimited.

Title: Uncertainty, Sensitivity Analysis, and Causal Identification in the Arctic using a Perturbed Parameter Ensemble of the HiLAT Climate Model

Author(s): Hunke, Elizabeth Clare
Urrego Blanco, Jorge Rolando
Urban, Nathan Mark

Intended for: Report

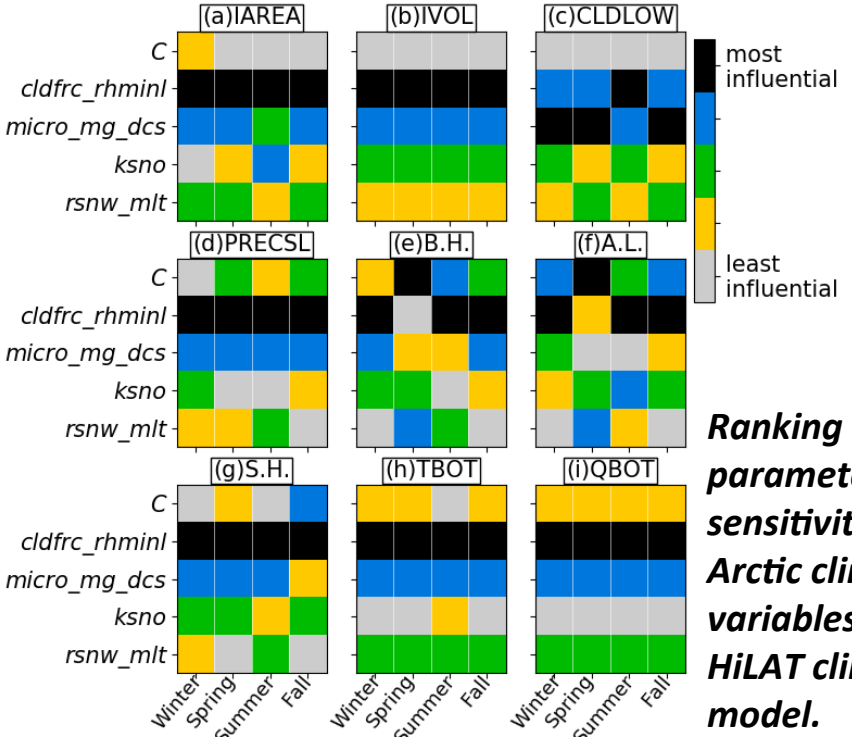
Issued: 2018-02-12

Disclaimer:
Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

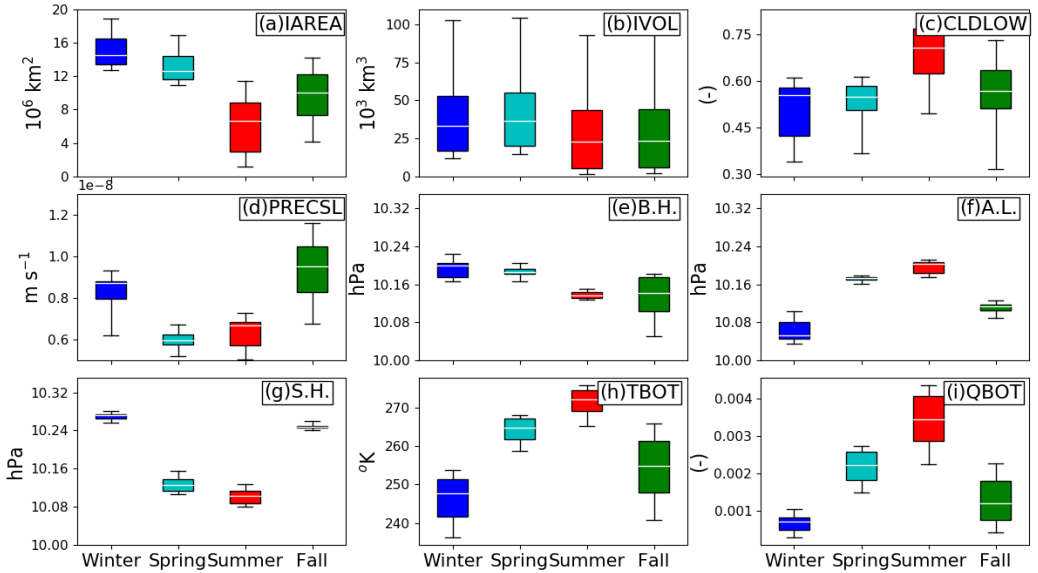
Uncertainty, Sensitivity Analysis, and Causal Identification in the Arctic using a Perturbed Parameter Ensemble of the HiLAT Climate Model

Elizabeth Hunke, Jorge Urrego-Blanco, Nathan Urban
T-3 Fluid Dynamics and Solid Mechanics, CCS-2 Computational Physics and Methods

Objective and Approach: Coupled climate models have a large number of input parameters that can affect output uncertainty. We conducted a sensitivity analysis of sea ice properties and Arctic related climate variables to 5 parameters in the HiLAT climate model: air-ocean turbulent exchange parameter (*C*), conversion of water vapor to clouds (*cldfrc_rhminl*) and of ice crystals to snow (*micro_mg_dcs*), snow thermal conductivity (*ksno*), and maximum snow grain size (*rsnw_mlt*). We used an elementary effect (EE) approach to rank their importance for output uncertainty. EE is an extension of one-at-a-time sensitivity analyses, but it is more efficient in sampling multi-dimensional parameter spaces. We looked for emerging relationships among climate variables across the model ensemble, and used causal discovery algorithms to establish potential pathways for those relationships.

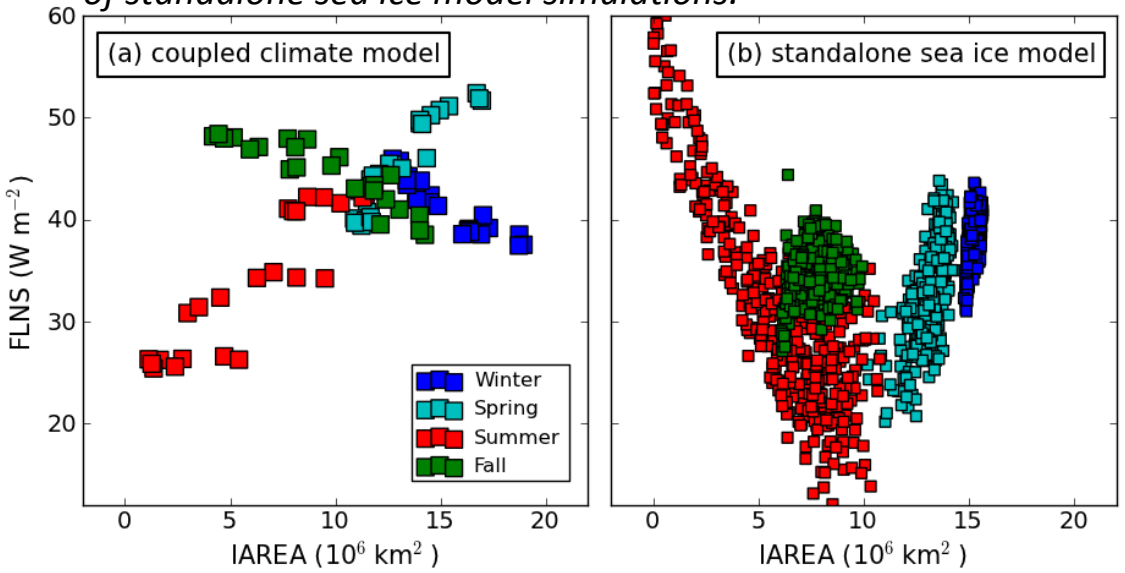


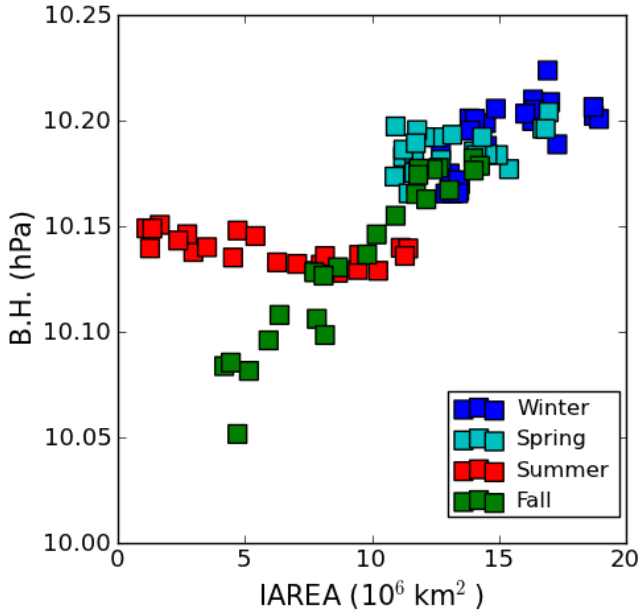
Ranking of input parameters for sensitivity of Arctic climate variables in the HiLAT climate model.



Uncertainty in model output from the ensemble of 24 coupled climate simulations: Colored boxes indicate the 25% and 75% percentiles, with the median value shown as a horizontal white line, and the whiskers span the minimum and maximum values for: (a) **IAREA**: total ice area, (b) **IVOL**: total ice volume, (c) **CLDLOW**: mean low cloud coverage, (d) **PRECLS**: mean large scale snow precipitation, (e) **B.H.**: mean sea level pressure over the Beaufort High region, (f) **A.L.**: mean sea level pressure over the Aleutian Low region, (g) **S.H.**: mean sea level pressure over the Siberian High region (h) **TBOT**: mean air surface temperature, and (i) **QBOT**: mean air surface specific humidity.

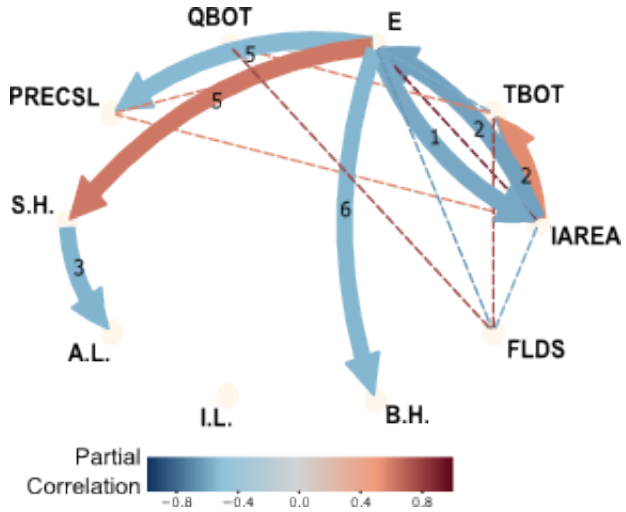
Relationship between the seasonal net downward longwave at the ice-ocean surface and the total Arctic sea ice area. Two distinct modes are identified in the melting and freezing seasons in the 24 coupled model simulations, which differ substantially from what is obtained in a 400-member ensemble of standalone sea ice model simulations.





Relationship between the seasonal Beaufort High sea level pressure and the total Arctic sea ice area in Fall. A strong relationship between them is identified in the 24 coupled model simulations in the Fall, suggesting strong coupling between sea ice and atmospheric circulation in the central Arctic.

<u>Impact:</u> We identified the relative importance of clouds, sea ice, and coupling parameters in simulating sea ice in a coupled climate model. The results have revealed mechanisms of ice-ocean-atmosphere interactions which can have impact for predictability studies. The results can also guide calibration of coupled climate models.



Causal network from 30-year Fall anomalies in the control coupled simulation. Arrows indicate significant relationships accounting for confounding effects from other variables. Dashed lines indicate significant relationships occurring at zero lag for which no causality can be attributed. A causal path may exist along ***FLDS (clouds)→ IAREA→ E (Evaporation) → B.H.***

This work was performed with support through LANL Institutional Computing project w17-seaice and DOE's Office of Science, Biological and Environment Research, Regional and Global Climate Modeling program.